Mathieu Dutré - Application Specialist MBSE

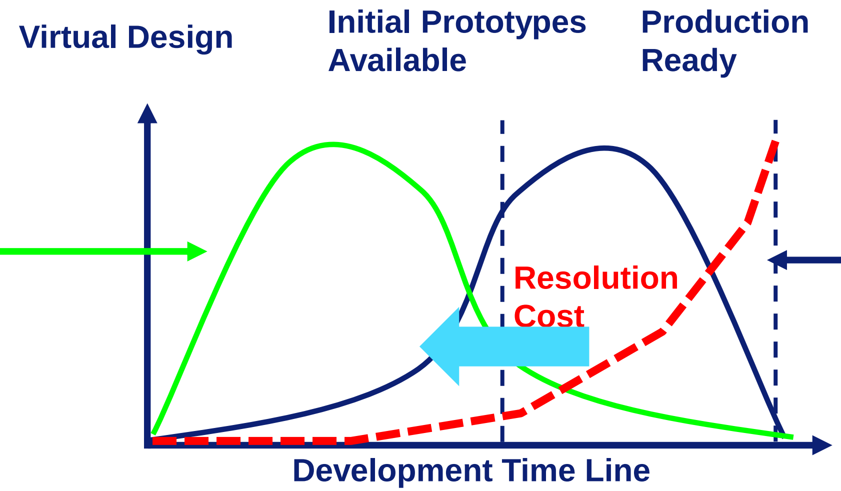
Analysis and optimization of physical models for HIL simulation

Smarter decisions, better products.

Industry drivers for HIL simulation

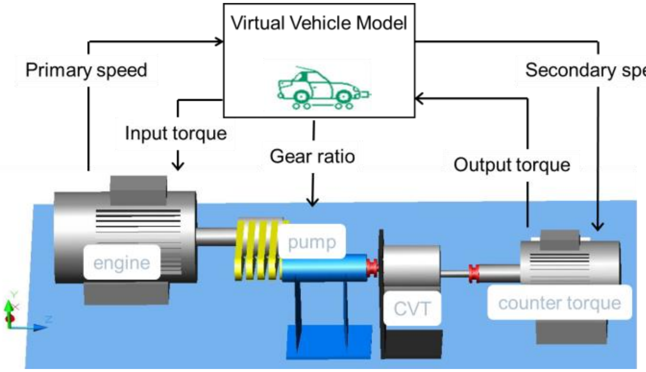
Model Driven

Generates usecases for HIL



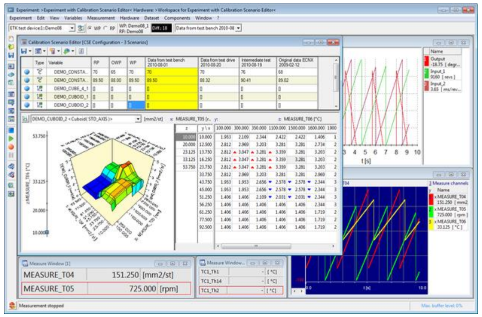
Prototype Driven

Frontload component testing



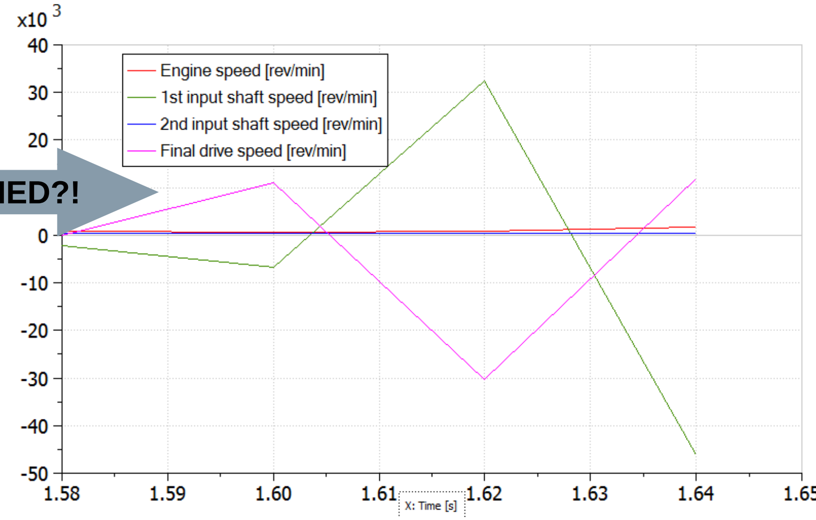
Driving Simulator

Controls calibration and validation



Why this session?

Prepare for HIL simulation

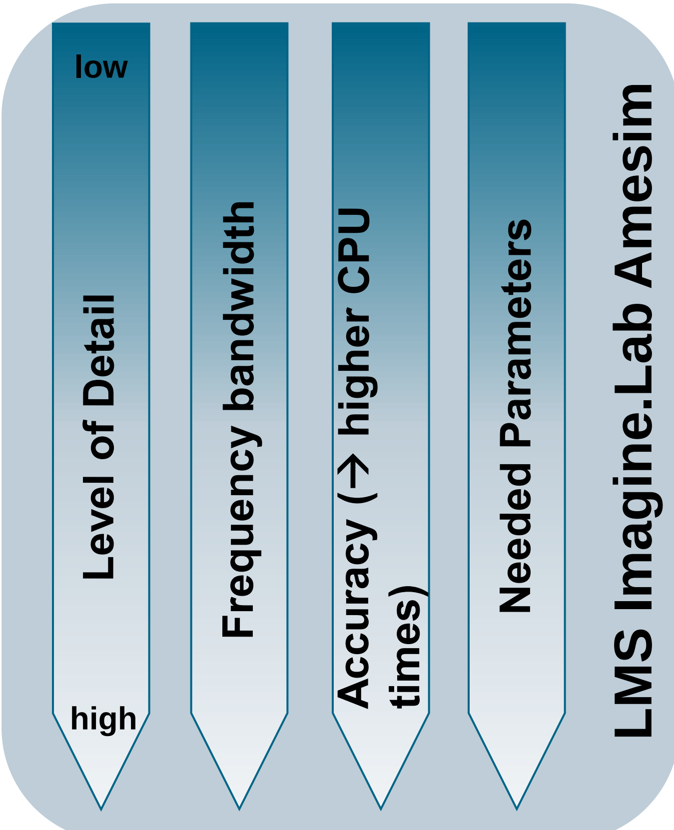


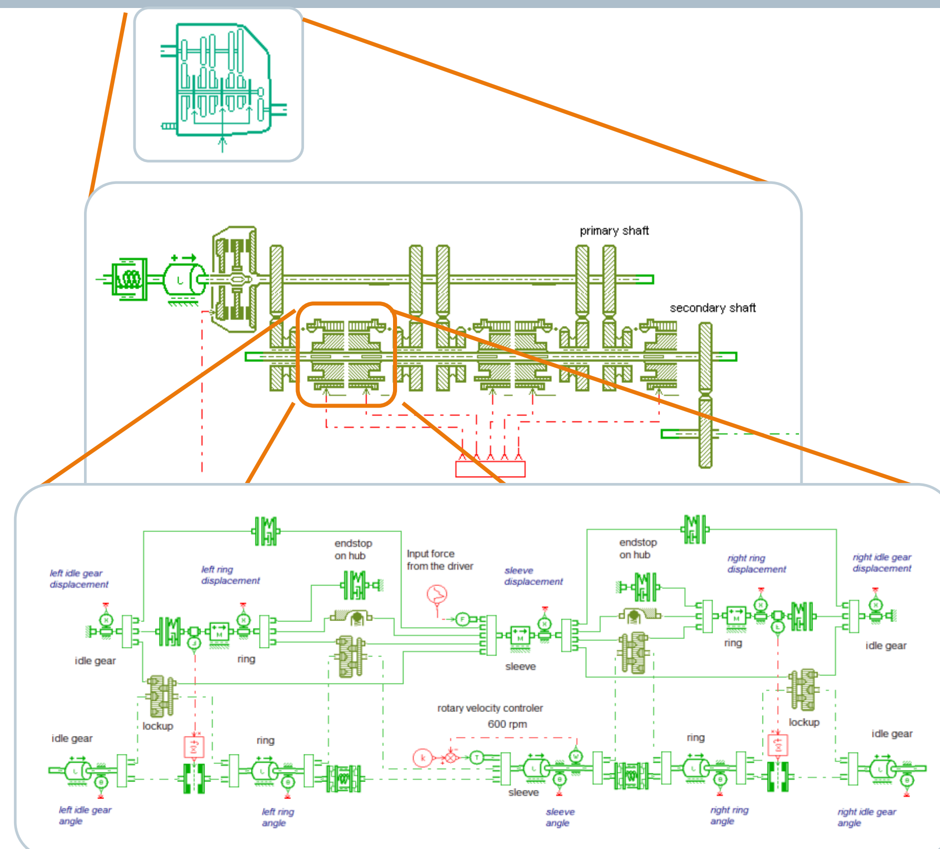
Provide support in the analysis and optimization of physical models prior to integration on an HIL system

- Understand reasons behind a "plant model crash"
- The different steps and need of model reduction techniques
- Connection between physical models and computer science
- Demonstration on the modal projection toolbox in context of HIL optimization
- Tricks to reduce the integration timestep requirements for your HIL platform

Selecting the right model using LMS Imagine.Lab Amesim

Prepare for HIL simulation





- The “proper model” is the one having the minimum complexity required to address the modeling objective (frequency range of interest)
- More details in your *.ame model, mean higher frequencies embedded in your model
- That could slow down CPU time in case these eigenvalues would be excited

Engineering questions prior to HIL integration

Prepare for HIL simulation

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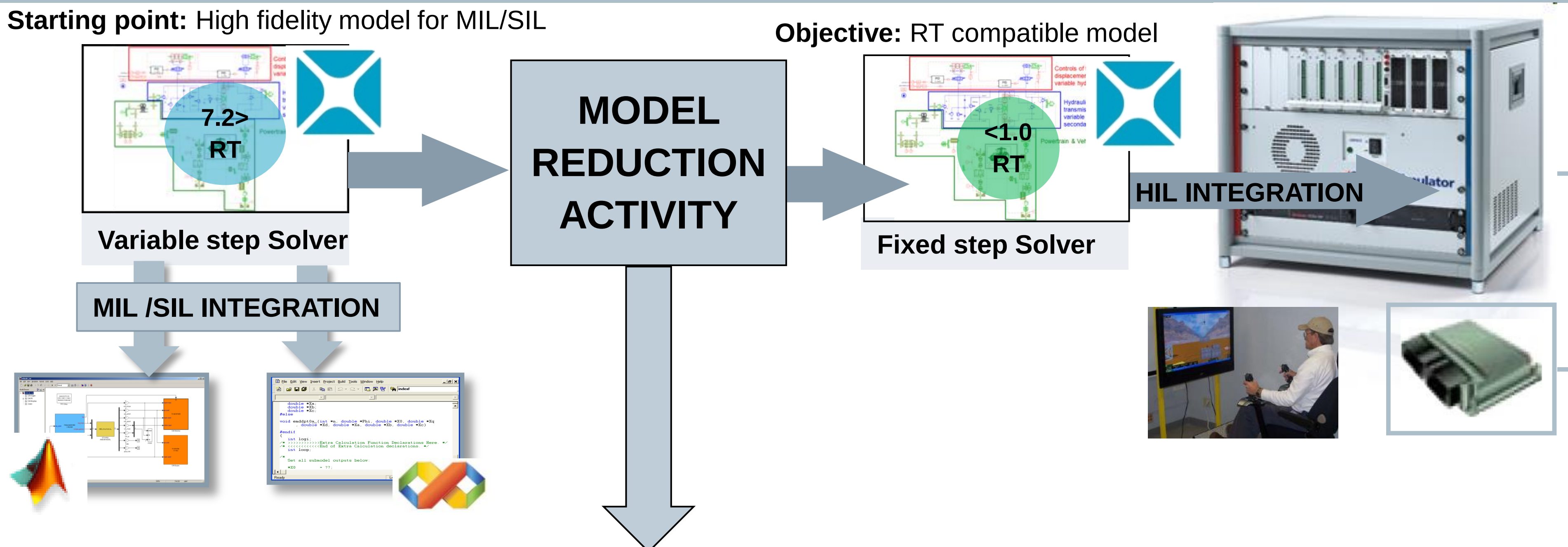
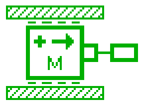


- What would be an appropriate sample time for my model on the for RT platform?
- Can I lower requirements of my sample time on the HIL platform by lowering my model fidelity or change parameters?
- What kind of physical component(s) is critical for the stepsize definition?
- What is the critical linearization time for the model?
- How to use my variable step solver model to analyze if my model is ready for a fixed step solver ?

How to connect physics to computer science?

Catch up with Systems Theory

Physical Models

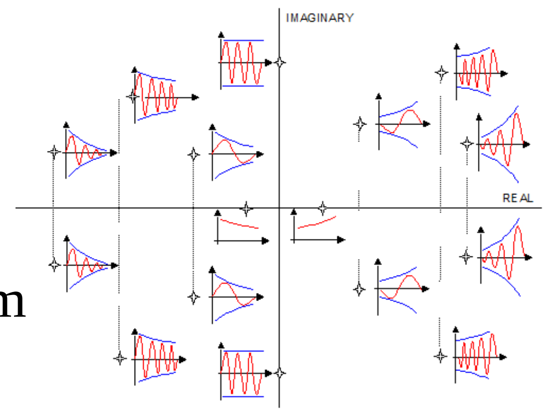


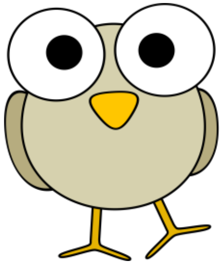
Differential equations

$$\begin{cases} \Delta\dot{x} = A.\Delta x + B.\Delta u \\ \Delta y = C.\Delta x + D.\Delta u \end{cases}$$

Eigenvalues

$$\lambda = \mathrm{Re} \pm j \cdot \mathrm{Im}$$





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Requirements for solver used on the HIL platform?

Integration Methods – Solver stability criterium
Catch up with Systems Theory

SOLVE

$\dot{x} = f(x, u)$

EULER

<u>*Numerical integration (ODE1)*</u>

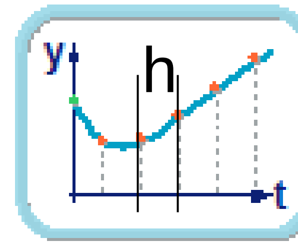
$$\frac{dx}{dt} \approx \frac{x_{n+1} - x_n}{h}$$

$$x_{n+1} = x_n + h.f(x_n, u_n)$$

$$x_{n+1} = x_n + h.\lambda.x_n + h.b.u_n$$

$$x_{n+1} = (1 + h.\lambda).x_n + h.b.u_n$$

[x_{n+1} is only a function of past values.
This is ok for real-time computation]



With $h = t_n - t_{n-1}$

(integration stepsize used on the RT platform)

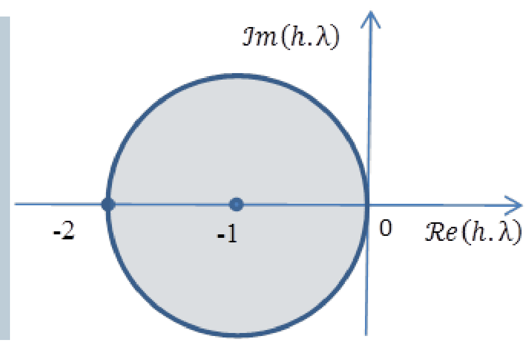
Assuming that the system is free ($u = 0$)

<u>*Stability criterium for ODE1 solver integration*</u>

$$x_{n+1} = (1 + h.\lambda).x_n$$

$x_{n+1} = a.x_n$ Or $x_{n+1} = a^n.x_0$ (*This equation converges only if* $|a| < 1$)

CRITERIUM for ODE1 INTEGRATION = $\mathbf{1 + h\lambda \leq 1}$



Connecting physics to computer science

Catch up with Systems Theory

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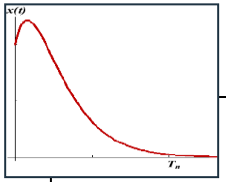
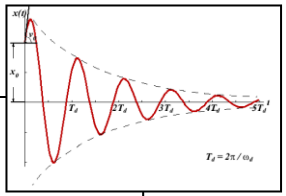
$$Fcpu = \frac{1}{h}$$

CRITERIUM for ODE1 INTEGRATION = $1 + h\lambda \leq 1$

$$\lambda = Re \pm j.Im$$





Faster system dynamics

Higher Eigenvalues

Thougher Requirements for RT solver

Overdamped: $\lambda = -R$

$$\left|1 - \frac{R}{Fcpu}\right| \leq 1$$

$$-1 \leq 1 - \frac{R}{Fcpu} \leq 1$$

$$-2 \leq -\frac{R}{Fcpu} \leq 0$$

$$\frac{R}{2} \leq Fcpu$$

Oscillating : $\lambda = -R + j.J$

$$\left|1 - \frac{R}{Fcpu} + \mathrm{j}.\frac{J}{Fcpu}\right| \leq 1$$

$$\left(1 - \frac{R}{Fcpu}\right)^2 + \left(\frac{J}{Fcpu}\right)^2 \leq 1$$

$$1 - 2\frac{R}{Fcpu} + \left(\frac{R}{Fcpu}\right)^2 + \left(\frac{J}{Fcpu}\right)^2 \leq 1$$

[The natural pulsation : $W = \sqrt{R^2 + J^2}$*]*

$$\left(\frac{W}{Fcpu}\right)^2 \leq 2\frac{R}{Fcpu}$$

$$\frac{W^2}{2R} \leq Fcpu$$

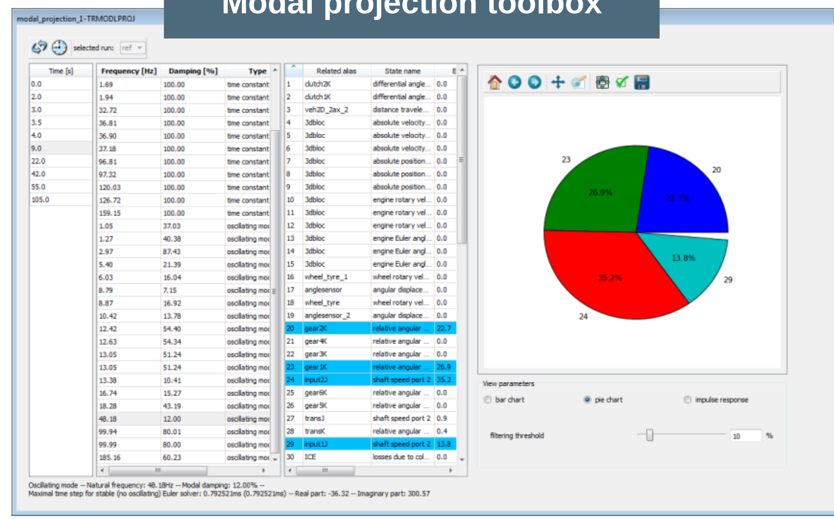
Tool for analysis & optimization of plant models for RT

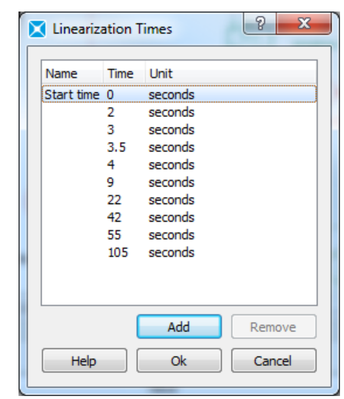
Catch up with Systems Theory

How to do analysis for a complex physical system?

- Highlight the worst linearization time
- Highlight the worst frequency
- Highlight the majors State/variables/ components involved in each frequency
- Identify the correct maximum time step to use with Euler Solver (fixed step)
- Find variables by their names

Modal projection toolbox





BENEFITS:

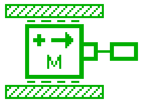
→ Adapt your level of model easily and fast, tune the value of parameters

→ Check that your simplified model is still providing accurate results

Model reduction workflow

Catch up with Systems Theory

Physical Models



Differential equations

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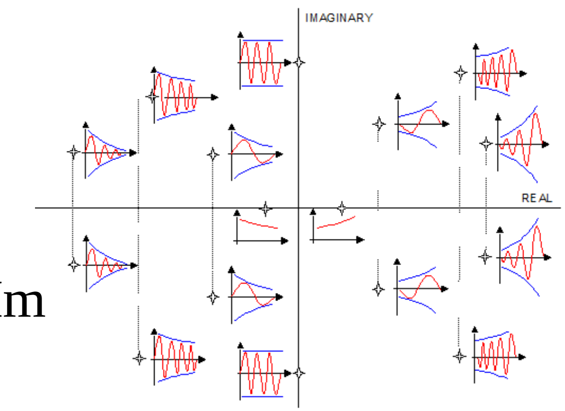
Eigenvalues

$$\lambda = \mathrm{Re} \pm j \cdot \mathrm{Im}$$



Stability criterium for Numerical integration

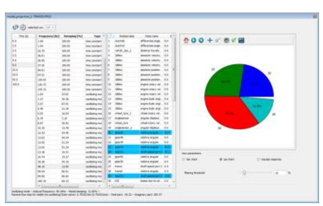
$$|1 + h\lambda| \leq 1$$

Requirements for F_cpu

$$\frac{R}{2} \leq Fcpu$$

$$\frac{W^2}{2R} \leq Fcpu$$

Model analysis and optimization



Starting point: a high fidelity model of the vehicle, its detailed transmission and actuators

Application example: Optimize a DCT model for HIL

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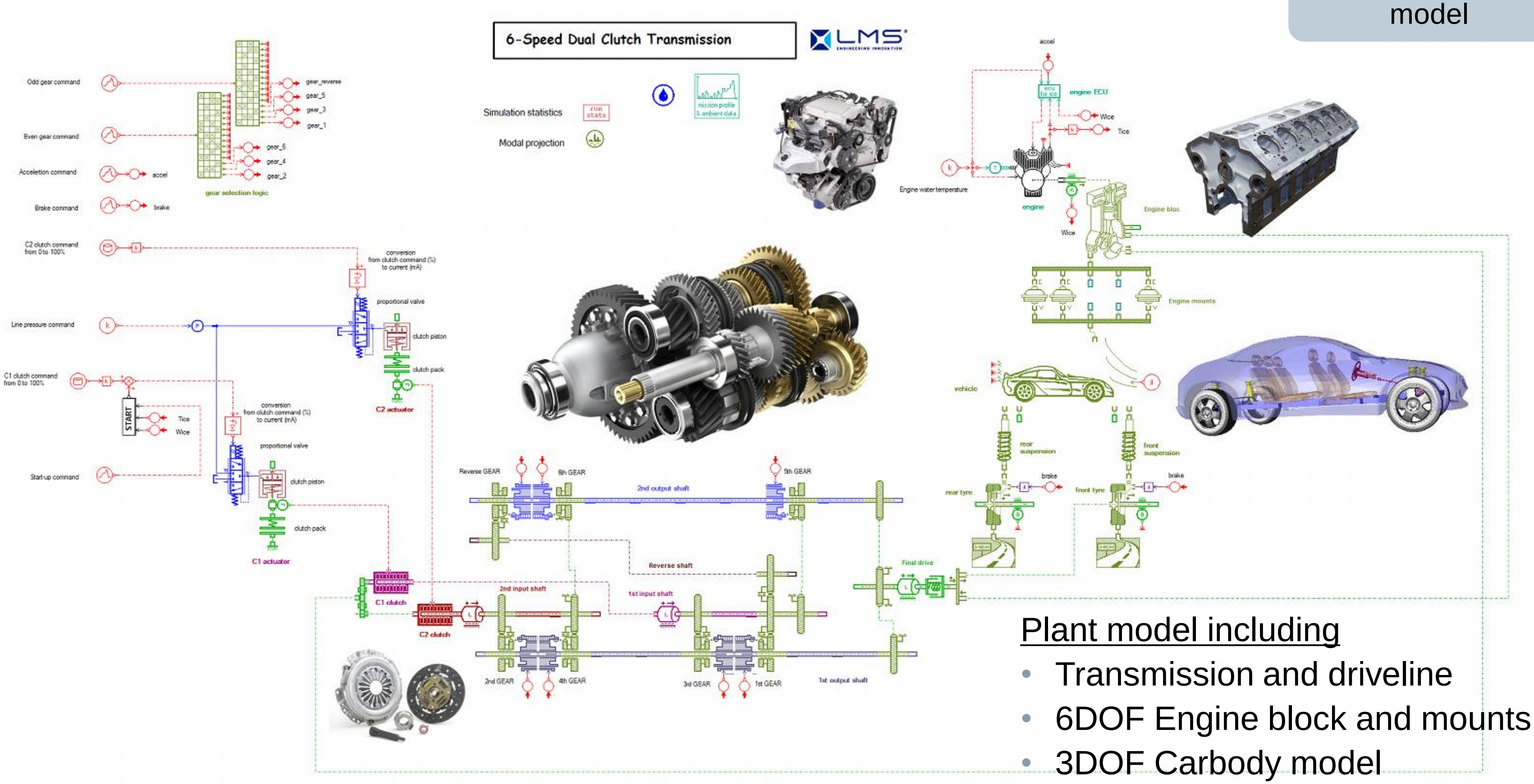
GOAL

Deploy the DCT model with a maximal integration timestep of 1ms

DCT vehicle model



<u>Plant model including</u>

- Transmission and driveline
- 6DOF Engine block and mounts
- 3DOF Carbody model
- Transmission actuators

Analyze and reduce a detailed model for fixed time step solvers and Real Time simulations

Application example: Optimize a DCT model for HIL

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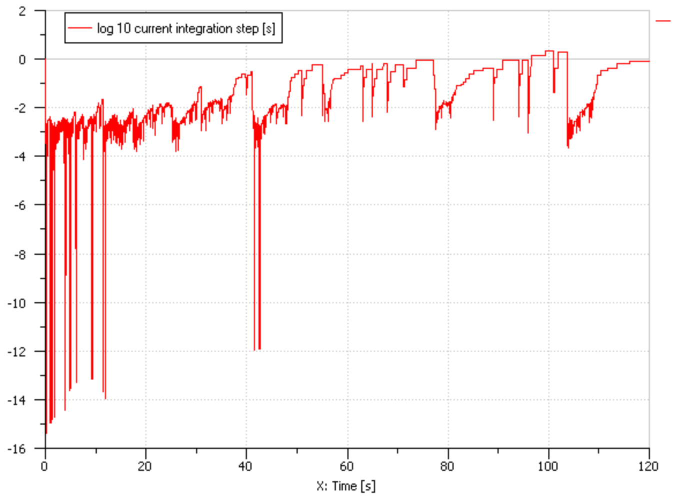
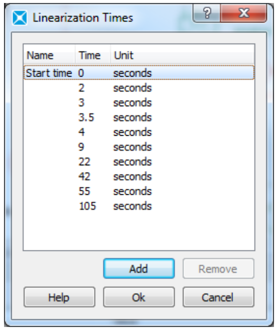
DEMO

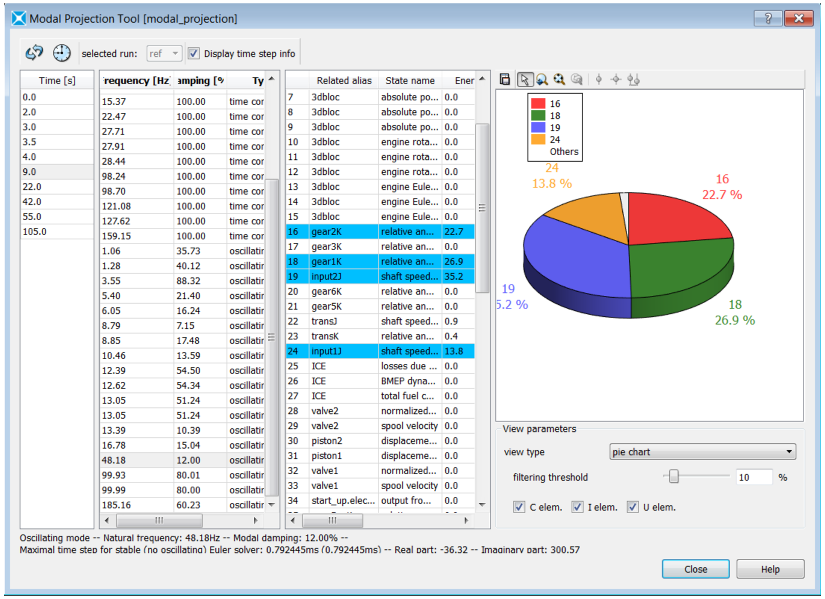
1)ANALYZE the integration timestep used by the variable step solver



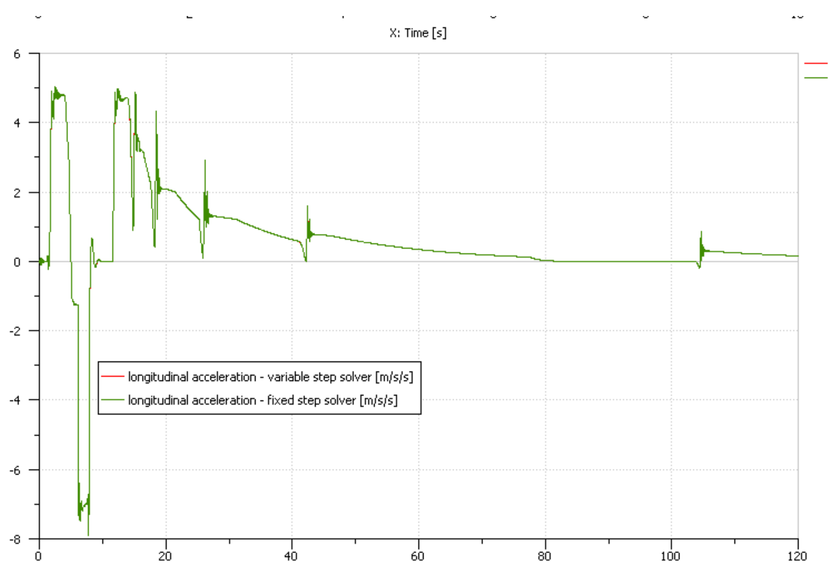
2) ADD linearization time for critical computation times



3) ANALYZE and OPTIMIZE the physical components and parameters for fixed step solver requirements

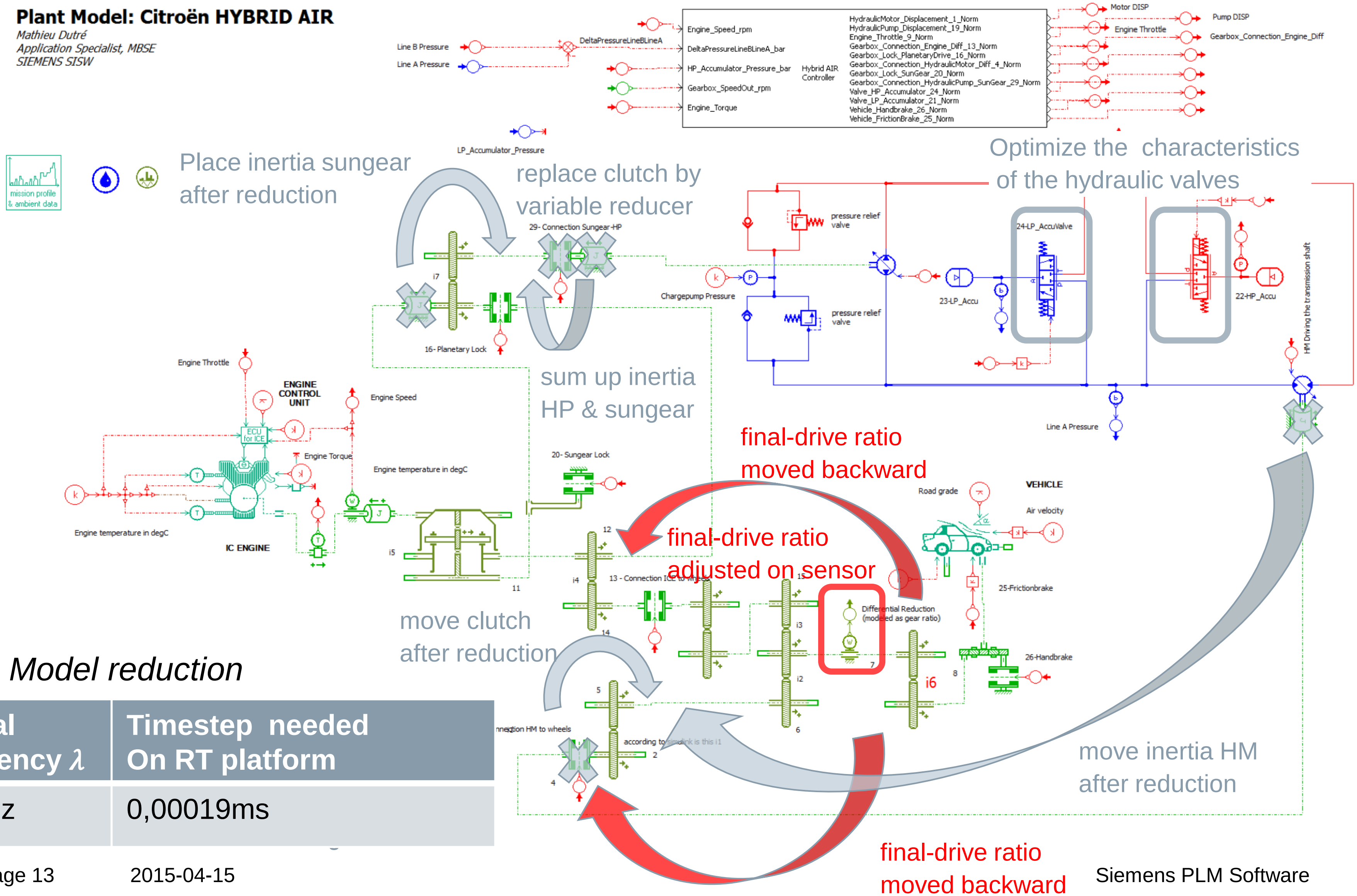


4) EVALUATE impact of fixed solver on model correctness



Typical changes towards HIL integration

Model reduction of a Hybrid Hydraulic vehicle

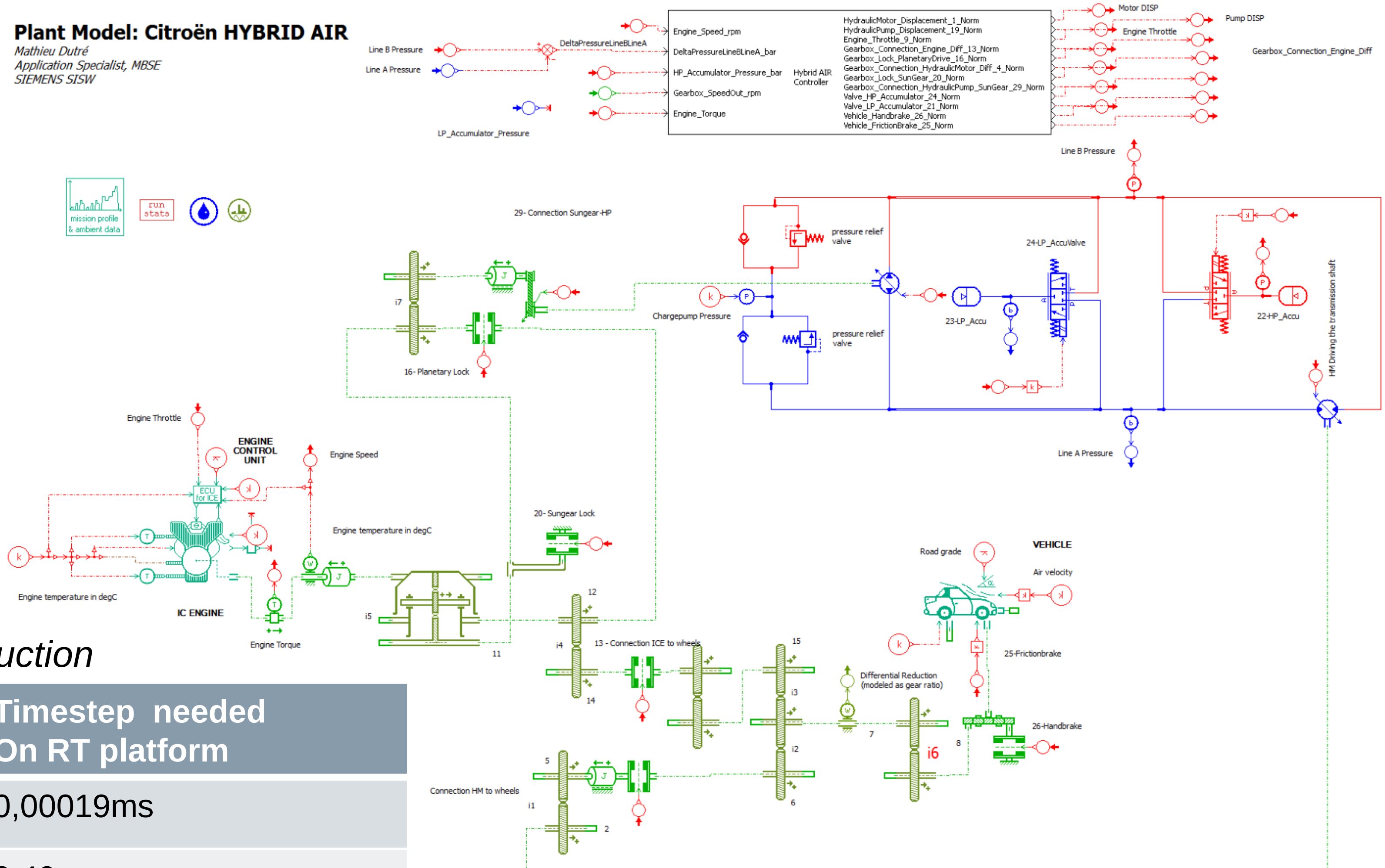


Before Model reduction

Natural Frequency λ	Timestep needed On RT platform
1.7MHz	0,00019ms

HIL compatible model

Model reduction of a Hybrid Hydraulic vehicle

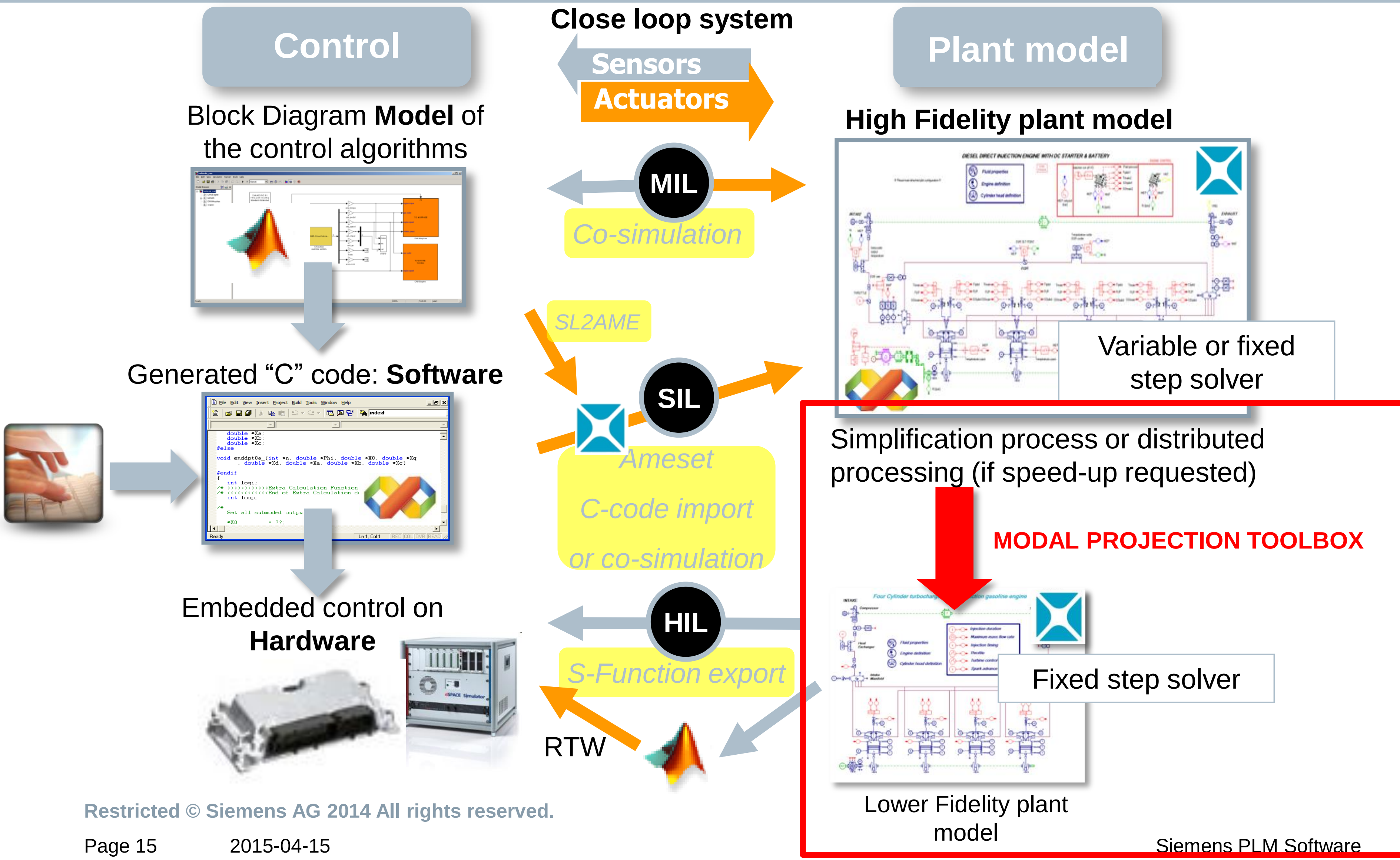


After Model reduction

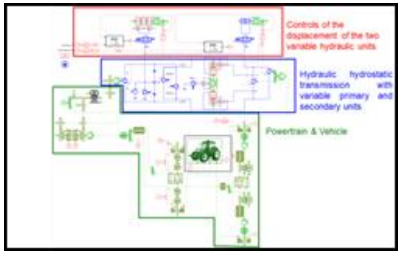
Natural Frequency λ	Timestep needed On RT platform
1.7MHz	0,00019ms
655Hz	0,49ms

There’s much more to say…

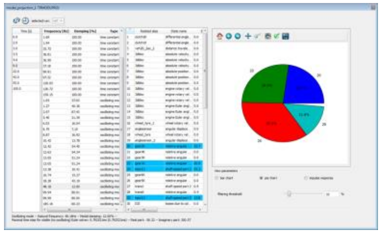
Siemens solutions for Solution setup for XiL



Summary



LMS Amesim: Platform to support you in physical modeling activities going from detailed component design to controls validation



Model reduction capability: Toolbox and process in place to support simplification of models towards HIL integration

Platform openness: Amesim allows HIL integration on a variety of HIL platforms

Knowledge transfer: Siemens PLM has specialized engineering teams that can support you in your challenges related to xIL testing.

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Thank you! Questions?

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